Long Term Goal 3: Tools to restore impaired aquatic systems and to forecast benefits of management alternatives

Introduction

To ultimately meet the goals of the Clean Water Act (CWA) States and Tribes need to restore impaired waters and to have measures in place that will protect these resources from unwanted degradation in the future. EPA requires them to develop Total Maximum Daily Load (TMDL) for impaired waters, and promotes a watershed management approach to achieve WQ objectives. Under the TMDL approach significant pollutant loading of point and non-point sources are identified and quantified, and estimates of acceptable loading rates are allocated amongst that it is estimated will bring the surface water body's water quality to a point where are the desired designated uses for that body can be achieved. Similarly, when new activities occur in a watershed increases in pollutant loads must be restricted so that water quality goals are maintained.

There are a number of factors that make this task extremely difficult. Practically all of the pollutant sources that can be easily measured and regulated – point sources – have been controlled to such an extent that they generally make up less than half of the remaining pollutant loading and the cost of further controlling them is high. This leaves non-point sources as the main target for control but these sources are generally large in number, their releases are diffuse and difficult to characterize, many of the means of controlling them are poorly understood and the Agency generally does not have regulatory authority to require specific types or levels of control in each type of non-point source. And the States and tribes, who are typically responsible for developing and implementing TMDLs, often have difficulty doing so because of the large programmatic resources required, the gaps in technical knowledge, and the social and political momentum to change due to the numerous stakeholders' interests must be balanced.

Once loading targets have been determined through the TMDL process, watershed management strategies need to be developed to achieve water quality goals.[1] As part of developing a watershed management plan, potential management measures and practices need to be identified, designed and implemented to achieve (or maintain) water quality goals. The term "Best Management Practices" (BMPs) is often used to describe the structural and non-structural technologies, procedures or other management practices used to prevent or reduce pollution loading. Selection and implementation of the appropriate BMP is very site specific and there are numerous gaps in our knowledge of their proper design and effectiveness.[2] Besides understanding what BMPs are appropriate to use, there are a number of other factors that need to be considered in the development and implementation of watershed management strategies. Examples include quantifying the economic benefits of restoration or protection, and cost-effectively optimizing the implementation of multiple BMPs in a watershed. Also, decision frameworks are needed to systematically consider these numerous factors.

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[1] *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, EPA 841-B-05-005, 2005. At: http://www.epa.gov/owow/nps/watershed_handbook/

[2] *The Use of Best Management Practices (BMPs) in Urban Watersheds*, EPA 600-R-04-184, 2004.

Despite these barriers, Congress and the Administration expect EPA to show progress towards meeting the CWA, therefore the EPA has set strategic goals for meeting these objectives. The Agency has also been asked to demonstrate the WQ improvements related to funding programs such as the 319 Program. OW's strategy for showing progress through 2008 include a number of milestones (Program Assessment Measures [PAMs]) that will require a strong technical basis for States and Tribes to develop and implement TMDLs. Other important drivers for LTG 3 research include requirements for municipalities to better control stormwater, leading to benchmarking best practices; the high costs of non-point source pollution control; and the general trend towards increased involvement of numerous groups of stakeholders in local decisions that can impact larger watersheds.

History of LTG 3-Related Research in ORD - From the inception of the EPA into the early 1990s, ORD was heavily involved in developing and demonstrating techniques for characterization and control of releases from municipal and industrial point sources. Starting in the 1980s ORD's research in this area started to decrease as more emphasis was placed on hazardous waste management and disposal. In the 1990s the two main areas of risk management research were a limited biosolids and wastewater research program and a program addressing urban wet weather flow, where much of the work was focused on management and control of combined sewer overflows.

Since the 1970's, ORD has been developing, improving and disseminating hydrologic fate and transport models. These models are in use for NPDES permitting and TMDL allocations, which is part of forecasting the effectiveness of management alternatives.

As the importance of non-point sources as the major impediment to meeting WQ goals became apparent, the LTG 3 research portfolio started expanding in the early 2000s. The portfolio is now comprised of research in the following areas:

- Characterizing the transport and fate of pollutants from the land to surface waters.
- Characterizing the transport and fate of pollutants within surface waters
- Determining how non-point source controls function and how they can be made more effective
- Determining how to best control releases from selected major sources of pollution
- Determining how to monitor improvements to water quality and aquatic ecosystems
- Determining how to best integrate the control, transport and fate and ultimate impacts of pollutant loads and the control of pollutant loads across time and space to cost-effectively achieve watershed WQ goals.
- Evaluating selected economic and policy options that play an important role in the development of watershed management strategies.

In the last five years our work has focused on the first three areas. Work on how best to control selected sources of pollution (fourth area) has been limited to those few with major technical uncertainties (e.g., concentrated animal feeding operations [CAFOs]).

Research in the remaining three areas has also been limited but is now expanding to address the important challenge of developing strategies that decision-makers can use to meet CWA goals effectively and efficiently by taking a watershed perspective to addressing restoration and protection problems. Stressors of concern in LTG 3 research are mainly nutrients, sediments, pathogens and flow, with some selected work on toxicants and potential toxicants, particularly emerging contaminants such as endocrine disruptors (EDC) (coordinated with ORD's EDC Research Program) and pharmaceutical and personal care products (PPCPs).

Several areas of ORD core expertise and associated research activities are involved in accomplishing LTG 3:

- landscape assessment and water quality modeling
- remote sensing and GIS analysis
- civil engineering
- microbiology
- stream and riparian zone ecology
- hydrology and biogeomorphology
- economics
- statistical analysis
- water chemistry

<u>Research Program Design</u>
The three science questions being addressed in LTG 3 are:

1. *What additions to models are most needed for the TMDL process? For habitat alteration? For nutrients? For suspended and bedded sediments? For pathogens? For toxic chemicals?*
2. *What BMP treatment systems and restoration technologies remain as uncertain options for watershed management? For mixed land use watersheds? For habitat alteration? For priority stressors?*
3. *How can classification schemes, modeling scenario analyses, landscape classification, and economic projections be applied to provide alternatives for meeting water quality goals efficiently at multiple scales? What are the economic benefits of watershed management?*

These three questions were selected because they represent areas of major uncertainty in the development and implementation of TMDLs and other watershed-based WQ management strategies. An understanding of the transport and fate of pollutants from uplands to surface waters and then within surface waters to locations where water quality is monitored is needed to establish pollutant loading and to forecast the effectiveness of WQ strategies. The performance of individual restoration techniques (i.e., BMPs) also needs to be known if realistic and cost-effective TMDLs are to be proposed. Modeling tools and guidance on the performance of WQ restoration options are critical to the implementation of OW's TMDL guidelines, 319 programs and Stormwater regulations, but they also need to be applied within effective decision-making frameworks. Science Question #3 captures the need to develop and test such frameworks.

Science Question #1 – Research to address this science question is taking 3 main forms: landscape-scale analysis, rainfall-runoff simulation modeling, and modeling of the transport and fate of stressors in surface water bodies. All three represent important components to development of TMDLs.

States are faced with a number of challenges as they develop TMDLs. These include determining where to focus monitoring efforts to characterize impaired streams, what the likely causes of impairments may be, where to put limited restoration funds, and how TMDLs might be allocated. While most restoration activities are ultimately done on a site-specific or watershed scale, landscape-scale spatial analyses play an important role in providing screening measures at a large geographic scale (state or region) and do so in a cost-effective manner. ORD research has resulted in the development of numerous tools that utilize geographic information systems (GIS) and geospatial data to perform landscape-scale analysis in support of the TMDL process. The Automatic Geospatial Watershed Assessment (AGWA) tool is a GIS interface for process-based hydrologic models that permits rapid relative estimates of water and sediment yields within a contiguous area. The Analytical Tools Interface for Landscape Assessment (ATtILA) which was developed at the request of EPA Regions and States to provide a comprehensive source for their landscape analysis needs has the ability to synthesize a wide variety of information at the landscape scale. Research is being conducted on the use of remote sensing to identify impervious surfaces that may impair water quality. Research has been initiated more recently on how to determine the water body recovery potential based on a variety of landscape metrics and help states prioritize restoration investments. **(Poster 3-03)**

To characterize and plan for the capture and treatment of urban wet weather flows, particularly for the purpose of meeting NPDES Stormwater regulations, many municipalities have been using the Storm Water Management Model (SWMM), first developed by ORD in the 1980s. SWMM is a dynamic rainfall-runoff simulation model for single event or long-term (continuous) simulation of runoff quantity and quality. It is the only available model capable of performing a comprehensive analysis of wet weather loadings and control options. SWMM is used by hundreds of municipalities, contractors and others. In 2004 ORD produced SWMM5 which increases the scope of its analysis capabilities and provides it with state-of-the-art software capabilities to make it as user friendly and robust as currently possible. Additional modeling capabilities are currently being added to SWMM. **(Poster 3-01)**

To develop TMDLs, it must be possible to provide a means of relating pollutant loadings at a given site to pollutant concentrations at the site or downstream. ORD research is developing the models for this purpose. Two types of modeling research are in progress. First, research elucidating the biological and physiochemical processes to determine the fate of pollutants in surface waters is being undertaken so that these processes can be accounted for in fate and transport models. This is an area of limited research in the WQ

Research Program, with the emphasis primarily on the fate of nutrients in the water column, as well as some studies on the partitioning of chemicals (e.g., PCBs) with sediments.[3] Second, fate and transport models themselves are being developed and tested. The EPA Visual Plumes model is widely used for outfall design, NPDES permitting, mixing zone analysis and forecasting recreational exposure to bacteria. The Water Quality Simulation Program (WASP) is the most widely used EPA tool for nutrient-related TMDL calculations and field testing and laboratory research is being conducted to enhance this tool. **(Poster 3-02)**

States and others are heavily dependant upon EPA for models to use in their TMDL programs. As a result, ORD, OW and EPA Region 4 have established a national technical support center to disseminate modeling tools and supporting documentation and to provide training courses, online tutorials and user guides. Resources of this Watershed and Water Quality Modeling Technical Support Center can be accessed at www.epa.gov/athens/wwqtsc/index.html. **(Poster 3-02)**

Science Question #2 – In the past five years the focus of this research has principally been on the performance of conventional structural BMPs, since the basis for effective design and construction of even these widely -used systems is often poorly understood. Also, there is little data available that relates performance to design and environmental conditions, making it difficult to accurately recommend appropriate structural BMPs for all but a limited number of situations. [See footnote 2] In addition, research has assessed the best BMPs to use for selected pollutant sources like CAFOs and urban wet weather flow collection systems.

During the 1990s and early 2000s, ORD conducted research on characterization and control of Combined Sewer Overflows (CSOs) and to a more limited extent on Sanitary Sewer Overflows (SSOs). This work resulted in numerous technical guidance manuals and the development of innovative control techniques for suspended solids, nutrients, toxics and micro-organisms. A culminating product was the book *Management of Combined Sewer Overflows*, which was authored by ORD staff and provides a comprehensive description of CSO problems and their management. **(Poster 3-04)**

ORD is now conducting mesocosm research and other studies to characterize the basic processes that influence the performance of various standard BMPs towards priority pollutants, such as wetland removal of nutrients. Results of mesocosm work will then be verified through field studies on pilot or full-scale units. The principal pollutants of interest are nutrients and sediments, while work on pathogens is increasing. **(Poster 3-05)**

Two important products of the BMP research program are the *BMP Design Guide* and *The Use of Best Managements (BMPs) in Urban Watersheds*. The three volume design guide provides design information for three commonly used structural BMPs, as well as general BMP design guidance. It's audience include consultants and permitting engineers. The second document provides a broader overview of structural and non-structural BMPs, explaining the current state of knowledge about their selection, design,

[3] Research on this topic is also being under the ORD Ecology and Land Research Programs.

implementation and performance monitoring, and describing issues that need to be considered on a case-by-case basis due to our limited knowledge of how BMPs' function. The document is being used primarily by municipalities.

Besides "upland" BMPs (e.g., swales, retention ponds), the function and use of wetlands are a strong focus of ORD research. ORD is studying ways in which restored or constructed wetlands can be used to control nutrient and sediments runoff and in-stream concentrations, as well as to provide other ecological services. **(Poster 3-06)**

Research on structural BMPs continues in ORD, with the present focus shifting to swales and to low impact development (LID) practices, such as green roofs. Understanding LID practices is important because they are being promoted as an important component to sustainable development. While in theory the idea of reducing peak volume of run off is a good one, limited data exists to show that there will not be undesired impacts (e.g., groundwater contamination) and as with BMPs in general, a basis for effective design, implementation and monitoring has not been well established. **(Poster 3-04)**

In the early 2000s research was initiated to better characterize releases from Concentrated Animal Feeding Operations (CAFO) and determine how to control those releases. CAFOs are point sources under the CWA and EPA was developing NPDES regulations which were ultimately promulgated in 2003. While CAFOs are covered by the NPDES program, much of their releases are in the form of non-point discharges to ground and surface waters such as run-off from fields or leaching from storage and treatment lagoons. ORD supported the development of the 2003 regulations and provided a state-of-the-art assessment of existing options for releases control: *Risk Management Evaluation for Concentrated Animal Feeding Operations*. Current research has investigated improved ways to implement the requirements of the 2003 regulations (which focus on controlling nitrogen releases through the application of USDA Comprehensive Nutrient Management Plans [CNMP]), and is determining the extent to which pathogen releases to surface waters continue to occur and how these might be controlled.[4] **(Poster 3-07)**

Science Question #3 – This science question is intended to address two types of research needed to support the ultimate formulation and implementation of watershed management plans. One is the development and demonstration of additional tools (e.g., economic benefits valuation) that are not addressed under the first two LTG 3 science questions. The second is the actual development of decision frameworks that Regions, States and local managers could employ to effectively formulate and implement watershed strategies. ORD research primarily addresses the first objective, but in the process is developing decision frameworks for specific water quality management problems. Research for this science question consists of:

- developing approaches to evaluate ecological benefits,
- looking at the application of existing economic valuation techniques to assess the economic benefits and costs of restoration scenarios,

[4] Research on ground water contamination from CAFOs is described in **Poster 2-07**.

- exploring market incentives for wetlands replacement or for the use of wetlands for “nitrogen farming,”
- developing an integrated science of watershed management.

States and tribes are provided limited latitude in adopting or revising designated uses and must carefully balance these trade-offs amongst health, ecological, institutional and socioeconomic considerations. Building on the EPA report *Integrating Ecological Risk Assessment and Economic Analysis in Watersheds*, ORD is developing a decision support tool that incorporates community preferences to evaluate the ecological benefits of attaining high water quality. Another ORD project is comparing how economic and emergy[5] metrics can be used as part of decisions on the allocation of limited funds to restoration projects. **(Poster 3-09)**

Pollutant credit trading programs have been used successfully to reduce air pollution and, if successful in water, could result in cost efficient improvements in water quality. ORD recently initiated a research to conduct pilot-scale studies of “wetlands trading” to support OW and Regional Offices in establishing a water quality trading program. This research addresses a key element of LTG 3 research which calls for the integration of economic decision-making into watershed planning and implementation. **(Poster 3-06)**

Of the numerous major challenges faced by decision-makers in developing an effective watershed management strategies, three important ones are: properly scaling management objectives to address the water quality impairment or protection problems, accounting for the natural attenuation of pollutants in surface waters, and linking pollutant load to impacts on biota over time and space. ORD research on integrated watershed science is addressing these issues. The watershed management framework used to organize these efforts consists of four basic components: 1) ecosystem analysis; 2) modeling delivery, transport and fate mechanisms for pollutants; 3) watershed planning through integrated, appropriately scaled, management decisions; and 4) water quality monitoring and adaptive implementation. To date some important tools that have been developed include: a) a method for evaluating BMP effectiveness based on flow-duration curves that is being used at the State level in Kansas and b) the development of a methodology to identify major sources of sediments and nutrients in a rural setting and evaluate the scale-dependant effectiveness of various BMP options. **(Poster 3-08)**

<u>Future Research</u>

Research will continue to address major uncertainties associated with each of the three science questions, with expanding activities to address the third. It is expected that as frameworks for watershed management are developed and applied, this will help to define the most critical uncertainties for the LTG 3 research program. Collaborations with USDA, USGS and others will continue to be important in order to leverage limited resources. And research under the ORD Ecology Research Program will provide fundamental studies in areas like ecosystem restoration processes and water quality processes.

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[5] One environmental accounting system expresses benefits and costs in terms of “solar emergy” or the available solar energy previously used up (directly and indirectly) to make a product or service